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ALUMINA
IN A MORE SUSTAINABLE WORLD

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About the Presenter

Andrew Furlong

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- B.E. (Chem), M.Sc. (Energy)

- 25+ years in the Alumina Industry
- Commenced in 1994 with Aughinish Alumina, Ireland
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Are we on the cusp of the Age of Aluminium?

- The Iron Age developed into the Steel Age that continues today.
- A sustainability focus demands lighter, more durable materials with strong recycling credentials.
- Will we see the Age of Aluminium?
- To progress, the industry must reduce its carbon footprint.

Energy Usage - Where have we come from?

Bayer Refineries – Process Energy Consumption

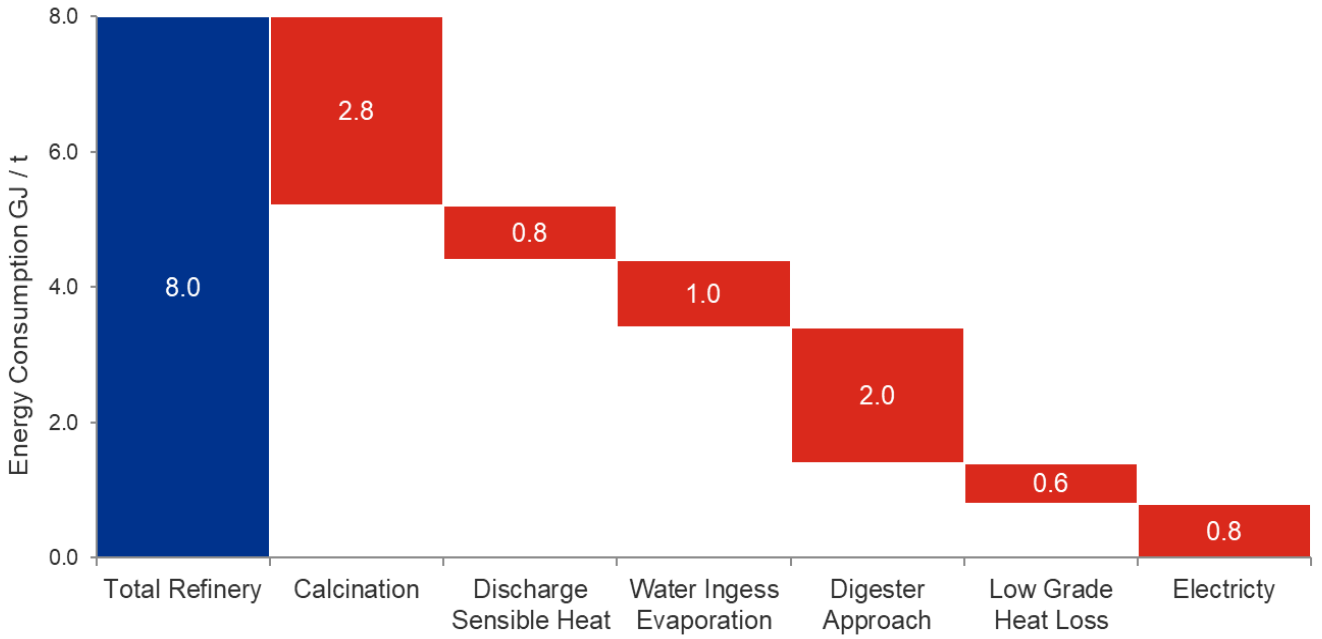
1890	1910	1935	1960	1965	1971	1980s	2000s
Batch operation, no heat recovery	Single flash heat recovery stage	Calcination kiln rotary cooling	Static Calciners, Plate Heat Exchangers	Single Stream shell & tube heating	Single stream tube in tube heating	Indirect Bauxite & Precip Slurry HX	Double Digest, FF Evaporator, MVR, Max HT

30 GJ / t → **7-8 GJ / t**

Sandy alumina yield Increase 50 to 100 g/L

Energy Usage – Where might we go?

- Energy usage will continue to decrease driven by:
  - Carbon social licence.
  - Pursuing competitive opex advantage.
- Energy reduction actualised by technology development – equipment & flowsheet.
- Chart demonstrates areas of opportunity.
- Energy efficiency will not take us to net zero emissions.



The Journey to Zero Carbon

Old technology.
Coal fired boilers
and grid electricity.
HFO kilns.
Low yield.
~1.6 t CO_2e / t

Current best practice.
Gas CHP, single stream.
~0.5 t CO_2e / t

The 2050 goal:
Net 0 kg/t CO_2e

World average:
~1.2 t CO_2 e / t Al_2O_3

Sustana
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Our response to the energy transition

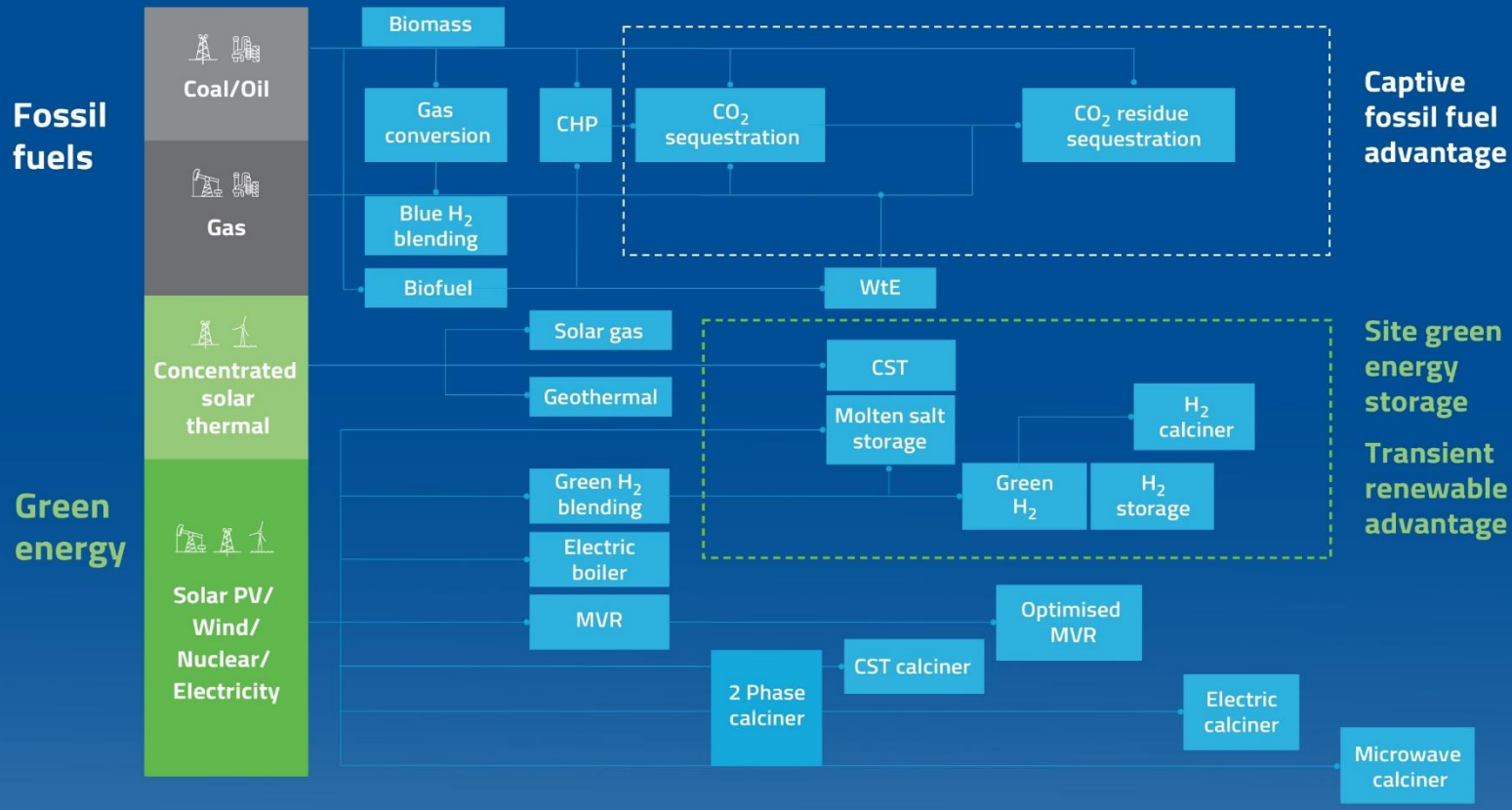
A look at Alumina

Legend:

TRL	Technical readiness level
CO_2	Carbon dioxide
CHP	Combined heat and power
H_2	Hydrogen
WtE	Waste-to-energy
CST	Concentrated solar thermal
MVR	Mechanical vapour recompression
PV	Photovoltaic

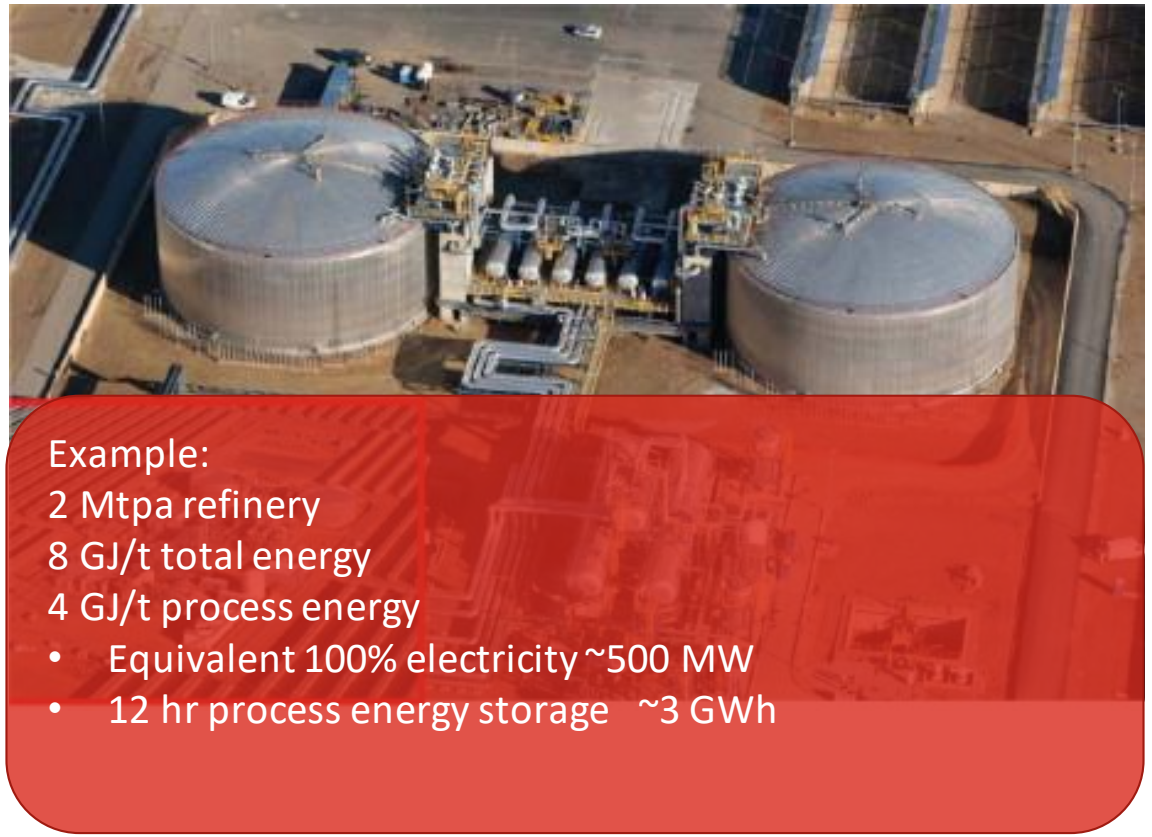
Sectors:

- Upstream & Midstream
- Refining & Chemicals
- Mining, Minerals & Metals
- Power & Water



Thermal Energy Storage

- Renewables are variable. Refineries need reliable energy supply.
- Numerous energy storage solutions are emerging.
- Refineries have the advantage of needing heat energy, reducing conversion costs.
- There is money to be made in “firming” electrical networks.
- Creates value through firming, improved access to low-cost renewables.

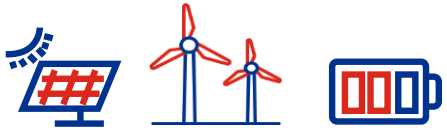


Example:
2 Mtpa refinery
8 GJ/t total energy
4 GJ/t process energy
- Equivalent 100% electricity ~500 MW
- 12 hr process energy storage ~3 GWh

Mechanical Vapour Recompression. Why not? Why now?

- MVR is proven technology in multiple industries.
- MVR not yet adopted in alumina
  - No economic driver. Electricity vs coal/gas pricing
  - Adaptation of technology required, notably flash steam quality in Bayer process.
- MVR is more energy efficient – no loss of latent heat. ~0.5 to 1GJ/t saving for MVR Evaporators.
- Drivers to push industry to adopt MVR
  - Expected initially in evaporation and then more broadly.

What Could This Look Like?



Solar PV / Wind / DES / Thermal Storage

Green equity / government support

Network: firming value

Refinery: Include thermal storage to firm decarbonised energy supply, take arbitrage advantage, replace/reduce live steam heating.

Region: accelerate renewables, economy of scale

Hydrogen

Initial user that underpins development of H_2 hub.

Offtake for blending into Calcination and/or CHP.

Calcination converted to fire on H_2 + O_2 removing CO_2, NOx, recovering water and providing O_2 sink.

Electrification

Electric Boilers

MVR Evaporation

Expanded application of MVR across Bayer Circuit

CCS Co-generation

Government funded Gas CHP to replace ageing coal-fired assets.

CHP efficiency synergy with export to smelter.

Long term refinery energy pricing with captive gas.

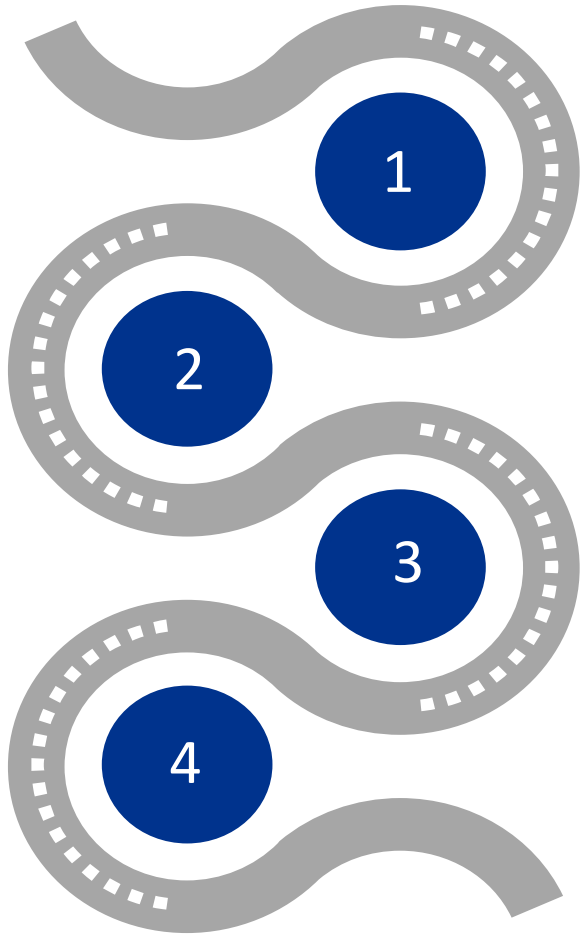
Utilise residue as CO_2 sink (neutralising / upgrading BR).

Synergies with local cement industry via residue as CO2 sink and/ or cement substitution.

Challenges Decarbonising Alumina

Technology Must Be Developed
Emerging competing technologies.
Transfer from other industries.
Technology maturation required.
Pick the right horse!

Complexity of Playing Field
Many potential pathways.
Path is site dependent.
Interdependency with electricity networks.
Be wise, learn from others' mistakes!

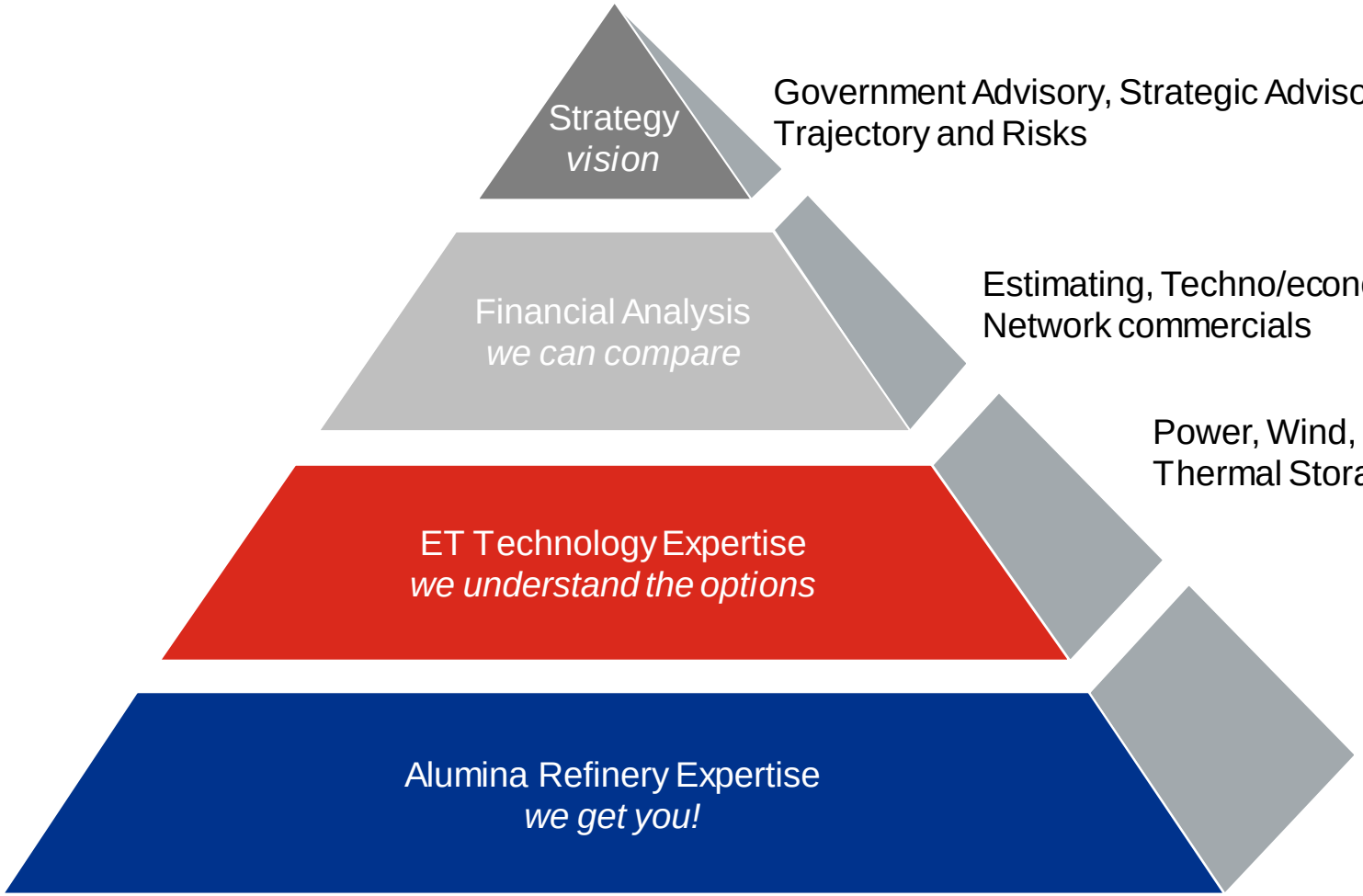


Timing is Set
Goals have been set.
Momentum is shifting.
Don't miss the boat!

Significant Investment Required
Optimisation of portfolio is critical.
What are the cost and risk trajectories?
Do *right project* then do *project right*.
Invest wisely!

Broad Skillsets Required

You need a good navigator for the Energy Transition voyage



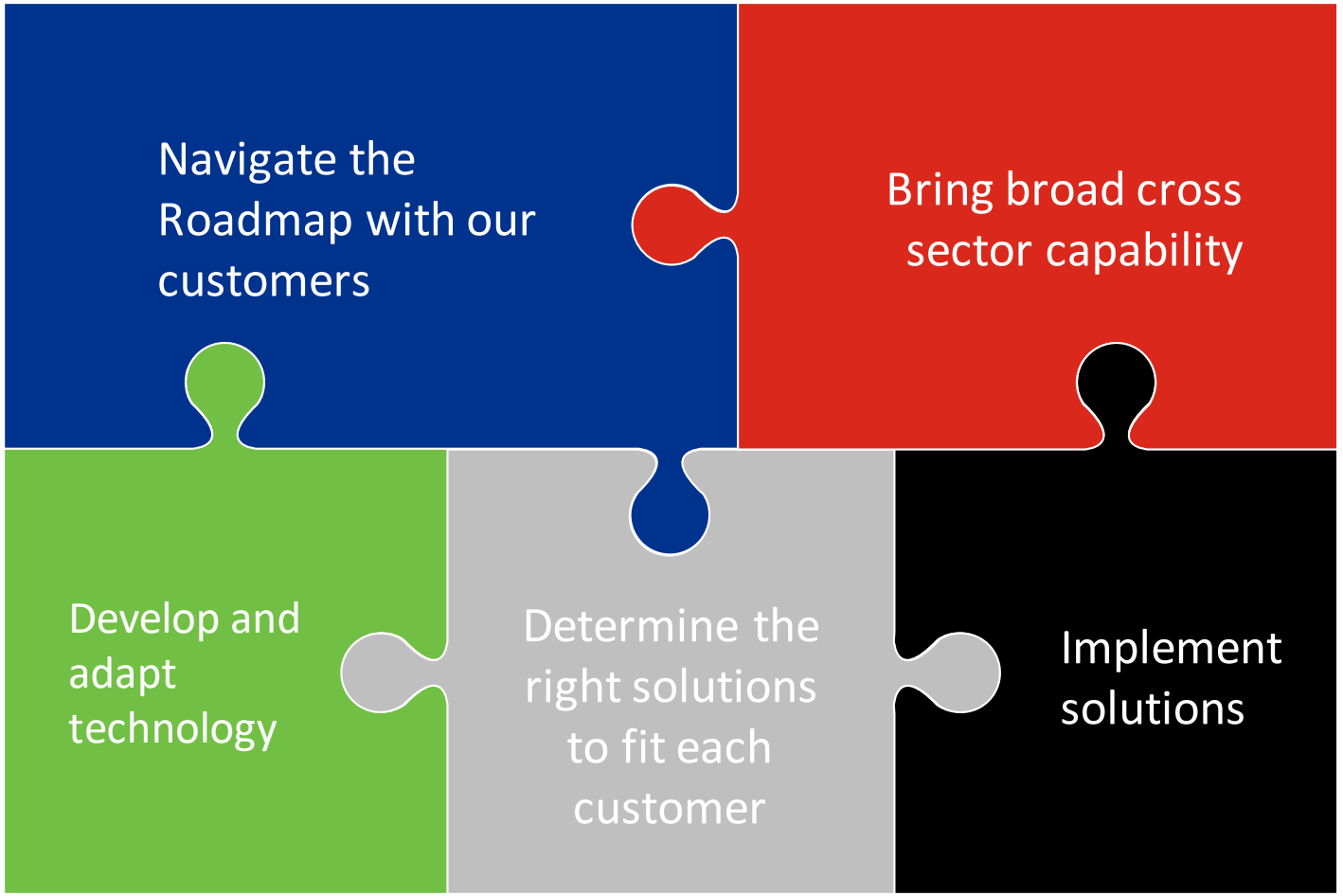
Government Advisory, Strategic Advisory, Decarbonisation Trajectory and Risks

Estimating, Techno/economic analysis, Energy Network commercials

Power, Wind, Solar PV, CSP, Battery & Thermal Storage, MVR, H_2, CCS, DES…

Industry leading Alumina Specialists, familiar with your site

Worley's Energy Transition Role



Worley delivering the Energy Transition

2360+ project experiences

Solar power	Wind power	Geothermal, hydro and ocean power	Nuclear power	Renewable fuels and waste to energy	Hydrogen	Distributed energy and storage	Electrification and energy efficiency	Carbon capture and storage
336+ Solar power projects	**685+** Wind power projects	**286+** Geothermal, hydro and ocean power projects	**216+** Nuclear power projects	**139+** Renewable fuels & waste-to-energy projects	**82+** Hydrogen projects	**218+** Distributed energy projects, electric vehicles and storage projects	**201+** Electrification, energy efficiency and grid transformation projects	**205+** Carbon capture and storage projects
950 MW World's largest CSP/PV hybrid project	**310 MW** Largest onshore wind farm (and largest in Africa) **2600 MW** Largest offshore wind farm	**20 GW** Largest hydropower project	**30+ GW** Nuclear projects over 55+ years, in 40 countries across 4 continents	**280,000+** barrels per day (4.29 billion gallons/year) of renewable fuels from 34+ projects	**36 GW** Largest green hydrogen electrolyser studied, combined with offshore wind	**30 MW** Largest battery energy storage project	**$20m/yr** Savings achieved through energy efficiency and electrification for a single industry client	**100 MT** of CO_2 expected to be captured and stored on world's largest CCS project

Conclusion

- The Energy Transition will be an incredible journey for the sector!
- The Age of Aluminium is in sight!
- We need to navigate a careful course.
- Some may fail along the way…
- ..but there are rewards for those who succeed in adopting the right pathways.
- All aboard! It's time to set sail!